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Information and Communication Technology and Electric Vehicles — Paving the Way towards a Smart Community

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SUMMARY A smart community can be considered an essential component to realize a sustainable, low-carbon, and disaster-tolerant society, thereby providing a base for community inhabitants to lead a simple, healthy, and energy-saving way of life as well as ensuring safety, security, and a high quality-of-life in the community. In particular, a smart community can be essential for senior citizens in an aging society. Smart community enablers such as information and communication technology (ICT) and electric vehicles (EVs) can perform essential roles to realize a smart community. With regard to ICT, the necessity of a dedicated wireless sensor backbone has been identified. With regard to EV, a small-sized EV with one or two seats (Mini-EV) has been identified as an emerging player to support personal daily mobility in an aged society. The Mini-EV may be powered by a solar battery, thereby mitigating vehicular maintenance burden for the elderly. It is essential to realize a dependable ICT network and communication service for a smart community. In the study, we present the concept of trans-locatable design to achieve this goal. The two possible roles of EVs in contributing to a dependable ICT network are highlighted; these include EV charging of the batteries of the base stations in the network, and the creation of a Mini-EV based ad-hoc network that can enable applications such as safe driving assistance and secure neighborhoods.

key words: *smart community, ICT, EV, sensor network, dependable, ad hoc network*

1. Introduction

Environmental destruction and global warming have become serious concerns these days. It is speculated that oil resources will be exhausted within the next 30 years. In this light, there is an urgent world-wide need for the evolution of low carbon and sustainable societies. Clean energy development has been considered as one of the obvious solutions, and nuclear power can be included as one source for clean energy. However, the recent nuclear power plant accident due to the Great East Japan Earthquake has raised significant concerns regarding the safety of nuclear power plants. Automobile exhaust has been one of the major causes of environmental pollution, and emission-mitigating hybrid cars and electric vehicles (EVs) have seen significant market growth. In particular, EVs, which are exhaust-free, are ideal to minimize air pollution in large cities, and they are expected to become increasingly popular with further reductions in cost.

On the other hand, the average age of the population world-wide has raised concerns regarding the approach of “aging” societies, particularly in Japan. This has in turn raised the urgent and controversial questions of how to adapt various social systems to such an aging society. In this light, we need to examine new approaches and guidelines for redesigning our society. In this study, we present the concept of a smart community as one such approach. Information and communication technology (ICT) and EV are essential tools to convey information, and transport people and materials in a smart community. In particular, this study focuses on the use of a sensor network with regard to ICT and the potential use of EVs to increase dependability and usability of such a sensor network in a smart society.

This paper is organized as follows: Sect. 2 presents the concept of a smart community and the roles of ICT and EVs in a smart community. Section 3 discusses the method of realizing dependable ICT networks in a smart community. Section 4 examines the possible usage of EVs for improving the dependability of ICT networks. Section 5 concludes the paper.

2. Smart Communities, Information and Communication Technology, and Electric Vehicles

2.1 Concept of a Smart Community

The term “smart community” has been used in various contexts. These days, it is often used in connection with smart grids and related areas [1]. The major interests in this context include energy efficiency and energy self-sufficiency in a community. In this study, we use the term smart community in connection with both energy efficiency and energy self-sufficiency, and improving the quality-of-life (QOL) particularly for the elderly in a community. Food security is also a major concern with increasing circulation of food contaminated with dangerous chemicals and bacterium under the global market economy. Consequently, food self-sufficiency in a community has attracted considerable attention world-wide recently [2], [3]. In this study, we characterize a smart community as follows:

- Efficient supply and consumption of all necessities and energy supporting human life and livelihood, including food, water, electricity, and gas
-Efficient processing of garbage and unclean water
-Efficient and low-carbon transportation of people and materials
-Maximum use of clean energy
-Simple and energy saving lifestyle with lesser load on environments

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-Safe and secure life
-Comfortable relations among residents
-High QOL for the elderly
-Self-sufficiency of food and energy
-Disaster tolerance and resilience

To realize such a smart community, several challenges need to be overcome, and innovations are needed both in social and technical fields. ICT and EV technology can be considered key players in the technical field.

Let us consider the way in which ICT and EV can pave the way towards a smart community. The basis of a smart community is an energy infrastructure that provides energy generation, distribution, and supply functionalities. The infrastructure for energy generation includes mega-solar plants and agricultural farms; that for energy distribution includes power transmission lines, water pipes, and roads; and that for energy supply includes electric-charging stations and convenience stores. Of course, such an energy infrastructure alone is not sufficient for realizing a smart community. An ICT infrastructure is essential to control and optimize the performance of the energy infrastructure under any condition. The ICT infrastructure includes the next-generation Internet; cloud computing; the next-generation cellular phones; ubiquitous sensor networks; smart phones; and smart meters. It is obvious that the ICT infrastructure must be highly dependable for stably and safely maintaining human life and activities in the smart community. This study highlights the novel approaches that can be employed to realize an ICT infrastructure that is dependable even in the case of large-scale disasters. In this regard, EVs are not merely an exhaust-free transport infrastructure but can potentially contribute to the realization of a highly dependable ICT infrastructure.

2.2 ICT Networks in a Smart Community

It is essential to optimally control the energy flow of electricity, water, gas, and human and vehicle traffic in a smart community. For this purpose, networks for simple energy transfer, such as power lines, gas pipes, water pipes, and roads, are not sufficient and require an ICT network, particularly a sensor network, for controlling the energy flow. The former may be compared to the blood vessel and the latter to the nerve system in a human body.

The ICT network may be classified into the categories of human and machine-to-machine communication. The latter includes sensor networks that are application-specific. The wireless sensor network (WSN) has attracted considerable attention due to the convenience of wirelessly networking a number of sensor nodes for various applications. Typically, a sensor node is a tiny device that has both sensing functionality and wireless-transmission and relaying functionality of sensor data. A WSN may be composed of a number of sensor nodes and a few sink nodes. The sensor data acquired at each sensor node are transmitted to one or more sink nodes directly (single hop) or indirectly (multihop). Recently, the standardization of wireless transmission technologies for WSN has been actively promoted under IEEE 802 standards, including IEEE 802.15.4g, IEEE 802.11ah, and IEEE 802.16n/p.

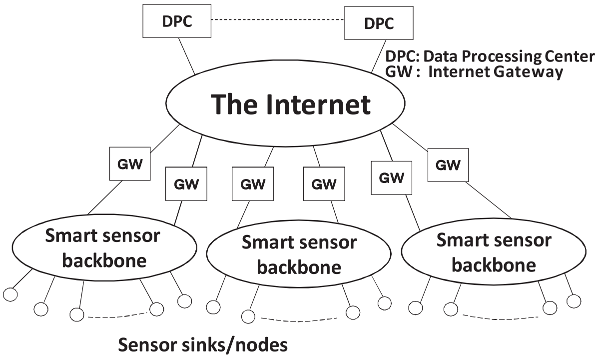

Fig. 1 Sensor network structure for a smart community.

In a smart community, a typical sensor node is a smart meter for measuring the usage of power, gas, and water in homes and offices. It is necessary to send sensor data from an enormous number of widely and densely distributed sensor nodes placed in a community to the Internet. A WSN can be used to collect data regionally. In addition a second network is necessary to convey the data collected by each WSN to the Internet over long distances; we term this network as the smart sensor backbone in our study (See Fig. 1). That is, both regional WSNs and the corresponding trans-regional smart sensor backbone compose a large-scale and wide-area sensor network. Further, wireless communication can be considered promising for such a smart sensor backbone. Conventional wireless WAN technologies including 3G and LTE can be used for the smart sensor backbone. However, such communication technologies and services have been developed for human use, and they are not always suitable for machine-to-machine communication in the smart sensor backbone. Accordingly, we require to develop a smart sensor backbone that is dedicated to collecting and transferring sensor data in a smart community. Typically, a number of base stations are deployed in a wide area to collect sensor data from the sinks of the WSNs or the sensor nodes in the neighborhood. In addition, the base stations are used as packet relaying nodes to send the data to the destination, i.e., one of the Internet gateways, over single or multihop wireless transmission in the smart sensor backbone (See Fig. 2). Low operating costs and low power consumption are essential to deploy a smart sensor backbone in each community. In addition, such a smart sensor backbone must be dependable to support smart community activities even during and after the occurrence of large-scale disasters.

2.3 Electric Vehicle (EV) in a Smart Community

Automobile exhaust has been a major cause of air pollution particularly in large-cities world-wild. The electric vehicle (EV) is being considered as an attractive alternative to cope with this problem. The major automobile manufactur-

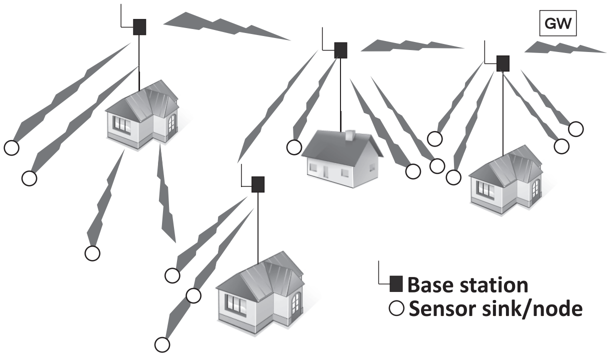

Fig. 2 Smart sensor backbone structure.

ers have been developing EVs that can deliver performances that are competitive the performance of conventional automobiles with gasoline-powered engine in terms of cost and continuous driving distance, thereby aiming eventually to replace the latter. Though these goals have not yet been fully achieved, the EV market has witnessed significant growth recently.

The essential advantages of EVs over gasoline-powered vehicles are considered ideal to realize the concept of the smart community introduced in Sect. 2. One of the serious problems in many communities in an aging society is the inconvenience caused due to changes in public transportation, such as withdrawing or reducing the frequency of bus lines that are non-profitable. In this context, the availability of a personal vehicle without CO_2 emission is indispensable in a smart community. A personal EV may be conveniently used to support personal daily mobility for activities such as shopping and nearby visiting particularly for the aged who may have difficulty in walking. Thus, personal EVs can improve QOL for the aged and contribute to the realization of an active mobile community that does not add to CO_2 emission. Unlike gasoline-powered vehicles, an EV has no mechanical engine and requires less maintenance, and this is convenient for the aged. It has been reported with respect to elderly drivers that the number of passengers is typically one or two and the driving distance is relatively less. In this sense, the use of small-sized EVs with one or two seats, termed "Mini-EV" in this paper, is promising. Refueling in gas stations is unavoidable for gasoline-powered vehicles, and this can be a possible significant burden for the aged driver. In contrast, a Mini-EV may be powered solely by solar battery, thereby removing the factors of cost and time for charging, and this can significantly mitigate the vehicle maintenance burden for the aged. Thus, Mini-EVs can potentially create a new EV market in an aging society.

Let us consider the feasibility of the solar-powered EV. Table 1 shows the specifications of two EV models, the Light-EV (4-seater EV) and the Mini-EV (2-seater EV). The solar panel size is assumed to be one half of the product of the length and width of the vehicle, and the weight of the solar panel is assumed to be 10 kg/m^2. Let W_v and W_b denote the vehicle body weight excluding battery and that of the battery, respectively. The weight of the vehicle including the battery, $W_v + W_b$, of each model is estimated from the linear correlation between the vehicle weight and the product of length, width, and height of the vehicle based on the statistics of existing EV products (Fig. 3). The battery weight is assumed to be 17% of the vehicle weight. Let D, C, and W_h denote the maximum driving distance, battery capacity, and the weight of the driver, respectively. A linear correlation between the energy consumption per unit distance driven, E (Wh/km), and the total weight, W, is obtained, as shown in Fig. 4. Here, $E = C/D$, $W = W_v + W_b + W_h$, and the values of D (typically JC08 mode) and C are set based on those of existing EV product information. The energy consumption per unit distance of each model is subsequently estimated by substituting $W_v + W_b + nW_h + W_s$ for W in the linear correlation above, where n denotes the number of passengers including the driver, and W_s denotes the weight of the solar panel. The performance prediction of the solar panel and EV battery is shown in Table 2. Assuming that the battery weight obtained as above is for the decade 2010–2020, the battery weight for future decades is derived by maintaining the same battery capacity as in 2010–2020 based on energy density prediction in Table 2.

Table 1 Electric vehicle specifications used in the study.

Parameters			Mini EV	Light EV
Length (m)			2.55	3.30
Width (m)			1.35	1.40
Height (m)			1.55	1.60
Area of solar panel (m^2)			1.72	2.31
Weight of solar panel (kg)			17.2	23.1
Battery capacity (kWh)			11.8	17.1
Room length (m)			1.27	1.64
Room width (m)			1.14	1.26
Room height (m)			1.20	1.23
Power Consumption (W)	Communication equipment		20	
	Air conditioning	Cooling	833	1220
		Heating	971	1460

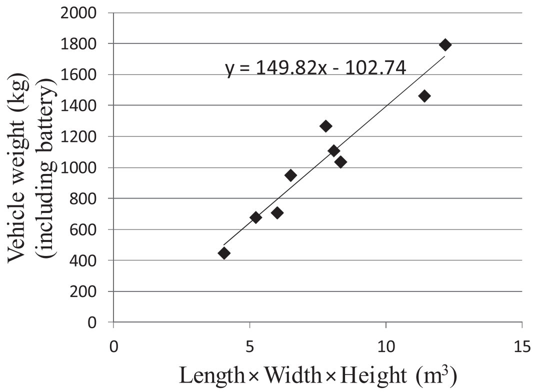

Fig. 3 Correlation between the vehicle weight and the product of length, width, and height of the vehicle.

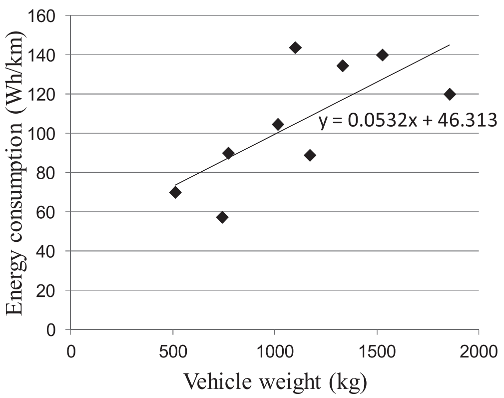

Fig. 4 Correlation between energy consumption and the weight of the vehicle including battery and driver (60 kg).

Table 2 Performance prediction of solar panel and EV battery.

	2010-2020	2020	2030	2050
Battery energy density (Wh/kg)	100	250	500	700
Solar panel module conversion efficiency (%)	16	20	25	40

The energy generated by the solar panel per day is calculated based on the amount of solar energy available in Tokyo per day for each season (Spring: March-May, Summer: June-August, Fall: September-November, Winter: December-February) [4] and the conversion efficiency prediction (Table 2).

Energy is not solely consumed for driving, but for air conditioning and in addition for communication using vehicle-based communication networks. Let us assume that the energy for air conditioning is expended during driving time and that for communication is used throughout the day. Consequently, the maximum driving distance per day, D (km), is given by the following equation.

$$D = \frac{E - 24P_C}{E_D - P_A/V} \tag{1}$$

where E (Wh) denotes solar-generated energy, E_D (Wh/km) denote energy consumption per unit distance driven, P_C (W) denotes the power used for communication, P_A (W) denotes the power for air conditioning, and V (km/h) denotes the average vehicle speed. The value P_A is estimated by calculating the energy required to maintain a temperature of 25 degrees Centigrade within the vehicle.

Assuming that the average driving speed is 10 km/h for the Mini-EV and 40 km/h for the Light-EV, and the number of passengers, n, is 2 for the Mini-EV and 4 for the Light-EV, the maximum driving distance for the Mini-EV and Light-EV per day without and with the use of air conditioning and communication for each season and for each decade are shown in Figs. 5 and 6, respectively. It is shown overall that the Mini-EV shows similar but slightly lesser performance compared with the Light-EV in terms of maximum driving distance per day. The solid and dashed line represent the maximum driving distance per day without and with air-conditioning and communication, respectively. The use of energy for air conditioning and communication significantly reduces the performance of the Mini-EV more than that of the Light-EV. It is noteworthy that the performance reduction is significant in summer and winter for the Mini-EV. Since it is assumed that the average speed of the Mini-EV is lower than that of the Light-EV, and that air conditioning is used during driving, the driving hours are longer, and consequently energy consumption is higher for the Mini-EV.

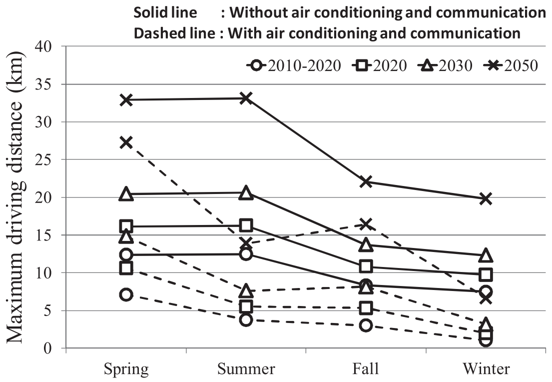

Fig. 5 Maximum driving distance of Mini-EV per day.

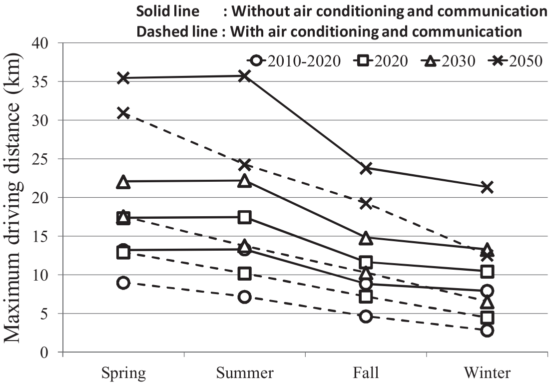

Fig. 6 Maximum driving distance of Light-EV per day.

The maximum driving distance per day is least in winter for both the Mini-EV and the Light-EV, when the solar generated energy is minimal and air-conditioning energy is highest due to the weather and temperature conditions in Tokyo. The driving distance is significantly extended by factoring the improvements in solar panel module conversion efficiency and battery energy density over years. If the Light-EV needs to be considered a viable alternative for today's gasoline-powered vehicle, the obtained performance seems unsatisfactory. On the other hand, the obtained performance is viable for the Mini-EV when used for daily short commutes, particularly for the elderly in a smart community. It is noteworthy that only innovations in solar panel module conversion efficiency and battery energy density are taken into consideration in the estimation above. Innovations in other areas, such as vehicle body material and EV system engineering may contribute to further improve the performance.

3. Toward a Dependable ICT Network and Service

3.1 Overview

The Great East Japan Earthquake and the resulting tsunami caused severe disruptions in the functioning of telecommunication systems as well as power supply systems. Strong traffic admission control measures were implemented to address the resulting traffic congestion. Traffic admission control is considered to be indispensable and unavoidable during large-scale disasters. Disaster recovery is performed using limited human and material resources on a best-effort basis. This is, however, a system-centric approach and may not be the most effective approach. Hence, it is necessary to explore and adopt a user-centric approach where traffic control can be minimized and communication quality through disaster recovery should be guaranteed in some form. A user-centric approach during a disaster recovery period may be characterized as follows:

- Anyone can use free-of-charge telecommunication services anytime without being subject to long waiting periods.
- Communication service is available at least within each shelter.
- A user can identify a communication partner easily through an accustomed way.
- Minimum communication service needs for survival should be satisfied.
- Certain privacy should be guaranteed.

Let us consider the conditions to realize a user-centric approach in disaster recovery, where a significant lack in human and other resources is unavoidable. Therefore it is firstly necessary to limit the telecommunication service area, for example, to shelters, where most evacuees come together and information transmission and reception are most requested. Along with telecom professionals, evacuees and volunteers may actively participate in realizing a minimal communication service. Users within shelters may not have any communication devices, while those outside the disaster area can communicate with anyone in the shelter by means of ordinary communication service.

Let us consider the next step towards realizing a user-centric approach. A fundamental problem during disaster recovery is that demand exceeds supply in communication services. In this situation, the two alternatives are to either increase supply or decrease demand. Increasing the supply of communication and other resources including trained personnel for any scale of disaster is obviously impossible. One possible solution is the trans-location of used facilities and equipment, as described in a later section. In the case of latter alternative, demand can be decreased by demand compression or demand flattening over time. Thus, voice conversation can be replaced by text-based communication and realtime communication can be replaced with non-realtime communication [5].

3.2 Trans-Locatable Design

Trans-location is the relocation of network facilities from the current location to locations where these facilities are urgently required [6]. The advantages of trans-location during disaster recovery include reduction in the use of emergency stocks, reduction of the need to buy new facilities, and reduction of the testing required before the network is operational. The network facilities used for providing communication services are required to be easy to dismantle, transport, and reassemble in order to realize a trans-locatable design. That is, the design should allow even those who are not telecom experts to perform these tasks. These facilities should at least be competitive in cost with conventional facilities, even when they are used over time at the original locations without trans-location. These facilities should be energy-efficient and accommodate the use of multiple power sources such as commercial power and solar panels in energy-limited circumstances such as large-scale blackouts. In addition, easy operation and maintenance are essential under limited professional support environments.

Trans-locatable designs may be applied to communication equipment such as satellite earth stations, cellular base stations, microwave relay stations, etc., as well as power equipment such as solar panels and batteries. The existing cellular base station coverage can be extended to cover disaster areas by adjusting the direction of the antennas and/or increasing transmission power without moving the base station itself. This is not a physical trans-location, but a virtual form of trans-location. In future, even energy itself may be trans-locatable by using EVs. EVs with communication devices may form mobile ad-hoc networks that are trans-locatable in nature. These novel challenges for trans-locatable design is discussed in Sect. 4.

3.3 Implementation of Trans-Locatable Design in Higashi-Matsushima City

Higashi-Matsushima City is located approximately 50 km northeast of Sendai, Miyagi prefecture. This city was one of the cities that were severely damaged by the Great East Japan Earthquake. Commercial communication services such as telephone and cellular services were not available in many areas in Higashi-Matsushima City after March 11. We proposed the provision of shelter communication service [5] in early April. The Miyato area was selected by the city authorities, and several surveys were conducted in April to provide shelter communication service in this area. Network construction was initiated in mid-May, and shelter communication service was provided by the end of May.

The proposed network structure is shown in Fig. 7 [6]. The city branch office is located at A, where power and broadband services were restored. An early human history museum located at D was used to provide food and other

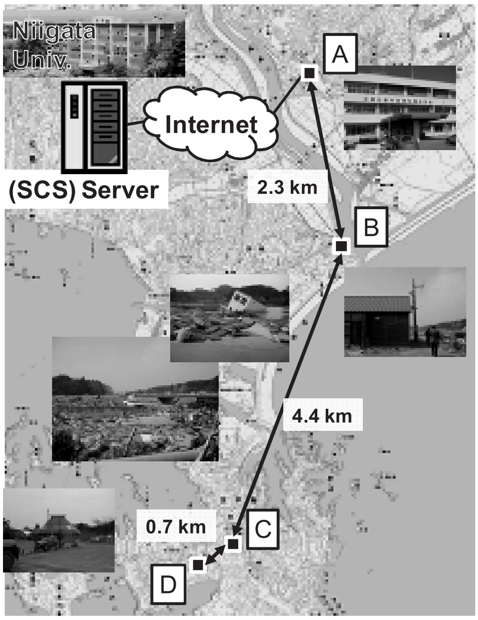

Fig. 7 Network configuration.

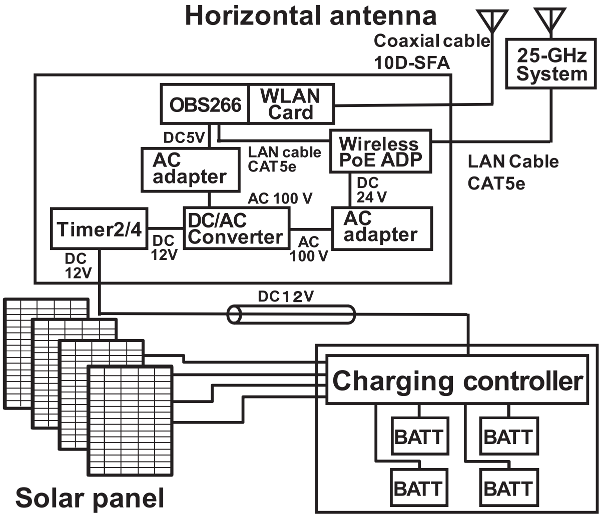

Fig. 8 Base station configuration.

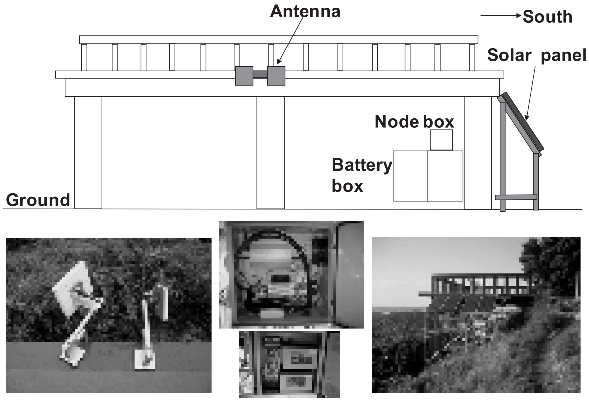

Fig. 9 Base station setup at location C.

daily necessities to evacuees in near-by shelters in the Miyato area. This museum was selected as the location to provide shelter communication service. Locations B and C were selected based on the survey as the most appropriate locations to set up base stations for providing wireless multihop connectivity between locations A and D. Location B is the sole line-of-sight location for both locations A and C. Power was not available at locations B and C, while an emergency power generator was used at location D.

Network construction was carried out based on the following guidelines:

-Optimal reuse of network facilities and equipment, which have been set up and used in the testbed of Niigata University and surrounding schools, based on the trans-locatable design approach. In particular, communication nodes, antennas, solar panels, and batteries are dismantled, transported, and reassembled.
-Directional antennas to be used for extending IEEE 802.11b transmission range.
-Usage of solar panels at locations where commercial power is unavailable. Battery capacity is designed to allow eight hours per day and three days of operation without sunshine.
-Minimization of on-site maintenance by daily rebooting of the micro-servers of the communication nodes to reset possible freezing of these micro-servers, and enabling remote monitoring support.

In the original plan, the IEEE 802.11b/g wireless LAN with directional antenna was used for each link. It has been confirmed that such a system can support transmission ranges up to 3 km in the testbed around Niigata University. In order to confirm that this system is also applicable to the 4.4-km link between locations B and C, we conducted experiments using actual communication equipment before network setup. Throughput of this system was very low (about 190 kbps), and this was not feasible for our requirements. The throughput of a wireless transmission system using a 25-GHz band, NTG-2500 [7], was also measured and as much as 15 Mbps throughput was obtained. Consequently, this system was used for the 4.4-km link. The IEEE 802.11b system was used for other links; locations A and B were linked by Channel 1 and locations C and D were linked by Channel 11, both having a transmission rate of 11 Mbps. The network equipment configuration and setup of the base station at location C are shown in Figs. 8 and 9. The TCP throughput was measured 5 times for a duration of10 s for each link and end-to-end along each direction. The measurement results are given in Fig. 10. This network has been providing shelter communication service since June 2011.

This project confirms that a trans-locatable design is technically feasible; a three-hop network was setup and made operational within one week using existing network equipment, solar panels, and batteries in Niigata University. However, the network planning survey on the site and the various discussions were time-consuming, and an interval of about 2 months was needed before providing shelter com-

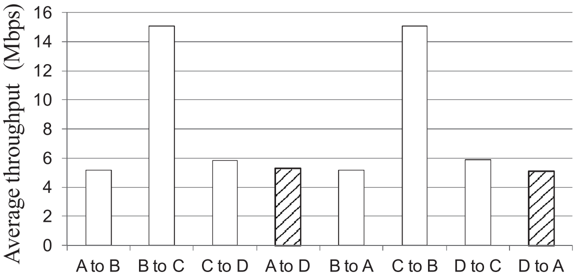

Fig. 10 Throughput measurements for the constructed network. (May 27, 2011)

munication service.

4. EV usage for Dependable ICT Networks

4.1 Use of EV for Power Supply

The Great East Japan Earthquake reinforced the fact that power supply to the ICT network is one of the most fragile components. Let us consider power supply to the base stations used to form ICT networks including the smart sensor backbone. The several available power supply alternatives are listed below.

A) Commercial power only
B) Commercial power, and battery
C) Solar panel and battery
D) Commercial power, solar panel, and battery
E) Commercial power, battery, and EV charging
F) Battery and EV charging

Power supply Type A cannot cope with power failure. Type B uses a base station with its battery charged over night at a lower price. It is popularly used for cellular phone base stations, but its continuous operation time under power failure is typically only a few hours; the extension of the battery power supply to 24 hours is under investigation after March 11. Type C may be recommendable in a smart community, but solar panels need relatively open and wide spaces; they may not be feasible under economical and space constraints. Type D provides of the advantages of both Types B and C [8]. Types E and F are novel approaches that we investigate in this study. Type E is similar to Type B except for EV charging. Battery charging is performed before it runs down due to power failure. Type F depends on periodical EV charging to charge a battery instead of the solar panel used in Type C. It is noteworthy that both Types E and F are examples of the trans-locatable design introduced in Sect. 3.2. Therefore, trans-locatable design thus may apply not only to industrial products such as communication equipment, but energy itself. The EV has a large-capacity battery, and it can be conveniently used to supply electrical energy. In Type E, EV charging is performed only during power outage while it is regularly used in Type F. Type F does not depend on commercial power distribution infrastructure, and this option is promising when solar power is available near a smart community.

Table 3 EV charging specifications for base stations.

	2010-2020	2020	2030	2050
Energy density	100	250	500	700
EV Energy (kWh)	20	50	100	140
Energy for charging	16	42	92	132
No. of stations for full charging	3	8	17	25

A typical EV charging performance is shown in Table 3; we assume that the battery capacity is 5.2 kWh (as in the case of the Higashi-Matsushima project mentioned in Sect. 3.3), the EV battery weight is 200 kg, and 8 kWh of energy remains in the EV battery for driving a distance of 80 km. It is observed that the number of nodes that can be fully charged by a single fully-charged EV increases with possible battery energy density improvements in the near future.

For EV charging, it is essential to know the remaining battery power at each base station to ensure efficient EV travelling, scheduling, and timely charging for each base station to avoid run-down of the battery. The ICT network itself can be used to collect such information.

4.2 Use of EV for Communication

In the history of the research and development of the mobile ad-hoc network (MANET), the vehicular ad-hoc network (VANET) has been particularly studied in the framework of the Intelligent Transport System (ITS). A vehicle is equipped with a communication device, and the vehicle itself can act as a communication node to form a mobile ad-hoc network with other vehicles. The presence of gasoline-powered vehicles is implicitly assumed in VANET research, and the applications of VANET during driving are of major interest. As mentioned in Sect. 2.3, the Mini-EV may prevalent in almost every household in a smart community. Under such circumstances, the Mini-EV can be a principal node in the formation of the VANET. An EV-based VANET is termed the EVANET (EV ad-hoc network) in this paper. An EV can work as a communication node for considerably longer duration than a gasoline-powered vehicle even during parking by using its battery when its motor is switched off. Therefore, the use of EVANET can lead to new applications during driving as well as parking.

The EVANET is essential to support safe and convenient driving, particularly for aged drivers in an EV-based smart community. An example of safe driving support is given in Fig. 11, where in addition to Mini-EVs, fixed base stations and other moving objects such as pedestrians and bicycles may join or interconnect with the EVANET. In a typical EVANET application, a base station at a cross-road collects GPS information from nearby moving objects and provides an object positioning map that can be used to avoid potential collisions. In Fig. 12, the EVANET is shown being used to locate a car in a large parking lot.

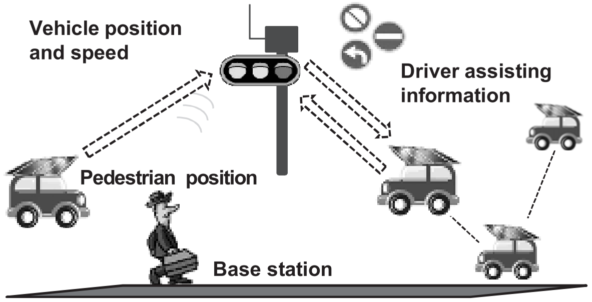

Fig. 11 Safety driving assistance.

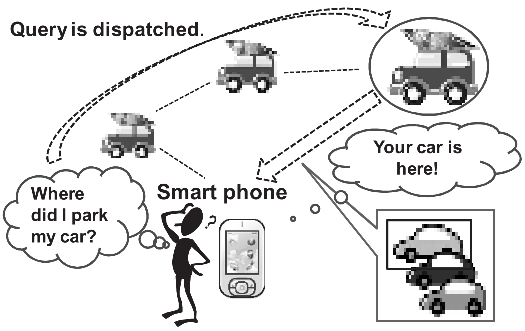

Fig. 12 Locating a car in a car park.

EVANET applications may not be limited only to driving situations. Several Mini-EVs may park in individual household parking lots during night-time and form an EVANET in a smart community; in such a scenario, the EVANET can act as a sensor network to detect and prevent crimes such as burglary. Broadly speaking, the EVANET can be used to improve QOL in a smart community.

Further the EVANET may be crucial during disaster recovery. When telecommunication services are degraded or disrupted due to the damage of network facilities and/or traffic congestion, the EVANET can function as secondary telecommunication infrastructure in a smart community. No time is wasted forming the EVANET. Public Mini-EVs owned by community government offices, together with those volunteered by individuals, can be distributed to form the EVANET. The surplus battery power available can be remotely monitored using the EVANET itself, and Mini-EVs that exhaust their batteries can easily be replaced with other Mini-EVs.

5. Conclusions

In this study, we presented the concept of a smart community, and we discussed the roles of ICT and EVs in realizing a smart community. A smart community is an essential component to realize a sustainable, low-carbon, and disaster-tolerant society, thereby providing a base for the inhabitants of the community to lead a simple, healthy, and energy-saving way of life as well as a safe, secure, and high QOL community life, particularly in an aging society. The role of ICT is to control flow of electricity, water, gas, and human and vehicle traffic in a smart community. The ICT network, particularly the wireless sensor backbone, is necessary to collect and send sensing data to the Internet. With regard to the use of EVs in a smart community, it is demonstrated that a small-sized EV with one or two seats (Mini-EV) may be an emerging player in enabling personal daily mobility in an aged society. The Mini-EV may be solely powered by a solar battery, thereby mitigating the vehicular maintenance burden for an aged driver.

This study emphasizes the importance of realizing a dependable ICT network and service for a smart community. We examine the idea of trans-locatable design to achieve this goal. Further, we examine two possible roles of EVs in the realization of a dependable ICT network. One is to use the EV for charging the batteries of the base stations of the network. The other is to connect a number of Mini-EVs with wireless communication devices, thereby forming an ad-hoc network, termed the EV ad-hoc network (EVANET), for providing facilities such as safe-driving assistance and neighborhood security.

A smart community is a new and challenging target to realize a low-carbon sustainable society, and several pertinent research issues need to be studied. This paper highlighted the mutual relation and collaboration between ICT and EV in a smart community. The research issues for realizing a smart community involves multiple disciplines. Research and development beyond the conventional scope of disciplines is essential to cope with this challenge.

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